EFFECT OF VARIOUS FAT SOURCES ON STARTER PIG GUT MORPHOLOGY AND NUTRIENT DIGESTIBILITY

D. F. Li, J. L. Nelssen, R. C. Thaler,
D. L. Harmon, and T. L. Weeden

Summary

One digestion trial utilizing 24 weanling pigs was conducted to compare the effect of various fat sources on gut morphology and ileal nutrient digestibility. Diets had either no added oil (control) or were supplemented with 10% either soybean oil, coconut oil or a combination of soybean oil and coconut oil (1:1 ratio). Pigs were sacrificed on 29 d of age, and ileal digesta were collected. Villus height and crypt depth were measured at the midpoint of the small intestine. Results indicate that pigs fed the combination of soybean oil and coconut oil had longer villus height and slightly higher ileal digestibility of medium chain fatty acids compared to the pigs fed either soybean oil or coconut oil alone. The reduction of villus height caused by feeding soybean oil or coconut oil alone may decrease the absorptive area and could result in inadequate transport of nutrient at the villus surface. The net result is a decreased nutrient digestibility.

(Key Words: Pig, Small Intestine, Digestibility, Fat.)

Introduction

Dietary fat addition has been shown to enhance performance of the early-weaned pig and to improve apparent digestibilities of fatty acids. Fat may influence nutrient digestibility by altering intestinal morphology. Previous research from this station has shown that pigs performed better on diets containing the combination of soybean oil and coconut oil (1:1 ratio) than on diets containing either of these oils alone. Dietary fat absorption may be related to changes in morphology of the small intestine. Therefore, the objective of this study was to investigate the effect of soybean oil, coconut oil, or a combination of these two fat sources on ileal digestibility of fatty acids and morphology of the small intestine.

Experimental Procedures

Composition of basal diets is shown in Table 1. The control diet in phase 1 contained (calculated) 1.3% lysine, .90% Ca, and .80% P. A constant calorie:lysine ratio of 250 calories/g lysine was maintained across all treatments within each phase. Therefore, diets containing fat had a greater percentage of lysine than the control diet to keep the calorie:lysine ratios of each diet similar. All fat sources were assumed to contain 3545 kcal ME/lb.

A digestibility trial was conducted to investigate the effect of supplemental soybean oil, coconut oil, or 50% soybean oil: 50% coconut oil on ileal digestibility of fatty acids, N, DM, and morphology of the small intestine. Twenty-four pigs (average initial weight 12.3 ± .5 lb)

Table 1. Composition of Experimental Diets[a]

Ingredients, %	Phase 1	Phase 2
Corn	42.20	45.55
Soybean meal (44% CP)	15.00	31.00
Dried whey	20.00	20.00
Skim milk	20.00	--
L-lysine HCl	.10	.10
D-L Methionine	.10	--
Salt	.25	.25
Copper sulfate	.10	.10
Trace mineral premix[b]	.15	.15
Vitamin premix[c]	.25	.25
Monocalcium phosphate (21% P,18.5% Ca)	.90	1.35
Limestone (38%)	.60	.60
Antibiotic[d]	.25	.25

[a]Fat (10% - phase 1; 5% - phase 2) and synthetic lysine (.25%- phase 1; .15% - phase 2) were substituted for corn in order to maintain a constant calorie:lysine ratio of 250 calories/g. Calculated analysis in the diet: CP, 19.5, 20.2; Lysine, 1.30, 1.25; Ca, .9, .9; P, .8, .8 % for phase 1 and phase 2, respectively.

[b]Provided the following in the per lb of complete diet (ppm): Zn, 70; Fe, 50; Mn, 25; Cu, 5; Co, .5; I, .7; Se, .3.

[c]Provided the following per lb of complete diet: Vitamin A, 2,000 IU; Vitamin D_3, 20 IU; Vitamin E, 6.67 IU; Vitamin K, 1.32 mg; riboflavin, 2.00 mg; niacin, 12.03 mg; d-pantothenic acid, 8.00 mg; Vitamin B12, 8.00 μg.

[d]Containing carbadox, 20 lb per ton.

weaned at 18 d of age were allotted randomly by litter, sex, and body weight to dietary treatments. Pigs were individually housed in stainless steel metabolism cages in an environmentally controlled room maintained between 85 and 90°F. Pigs were fed twice daily, and water was offered ad libitum. Pigs were brought to maximum feed intake during a 5-d adjustment period and then were provided with a constant feed intake during a 3-d collection period. Cobalt-EDTA, at .2% of the diet, was used as a marker to calculate ileal and total tract nutrient digestibilities.

Feces were collected and frozen daily throughout the collection period. All pigs were sacrificed at 29 d of age. Ileal digesta were freeze dried, and the feces were dried in a forced air oven at 122°F until equilibrated to a constant weight. Feces and digesta, along with diet samples, were ground in a coffee grinder. Ileal apparent digestibility coefficients were calculated for DM, N, energy, total fat, and fatty acids.

After pigs were sacrificed, the small intestine was uncoiled, and a 3-in. segment from the middle intestine was removed, rinsed with saline, then immersed in cold 10% formalin. The distal segment of intestine was stripped of its contents by infusing with 50 ml .15 M KCl. These contents were considered to be the ileum digesta of the small intestine. Digesta contents were stored at -70°F for future laboratory analysis.

Cross-sections of intestinal samples from formalin-preserved segments were prepared using standard paraffin embedding techniques. Villus height was measured on the stained sections at 10 X magnification using a light microscope equipped with an ocular micrometer. Height was measured from the crypt mouth to the villus tip at 10 μm increments.

Results

There were no differences in apparent digestibility of DM, total fat, CP, and GE among the fat sources (Table 2); however, pigs fed diets supplemented with 10% fat had higher ($P<.05$) apparent digestibility of total fat than pigs fed the control diet. Overall, the large amount of stearic acid (C 18:0) in the feces as compared to the amount in the ileal digesta resulted in lower apparent digestibility of stearic acid in total tract than that in ileal digesta (Table 3). The apparent digestibility of long chain saturated fatty acids was lower than that of short chain fatty acids, and the apparent digestibility of unsaturated fatty acids was higher than that of saturated fatty acids.

Pigs fed diets supplemented with 50% soybean oil : 50% coconut oil had increased ($P<.08$) villus height compared with pigs fed diets supplemented with either soybean oil or coconut oil alone (Table 4), which coincides with the slightly higher ($P<.12$) ileal apparent digestibility of medium ($C\leq14:0$) chain fatty acids from this combination. However, there were no differences ($P>.05$) in crypt depth among the fat sources or combinations.

Discussion

Pigs fed diets supplemented with 50% soybean oil and 50% coconut oil had longer and rounder villi compared to soybean oil and coconut oil alone. Whether the longer villi resulted from a suitable proportion of fatty acids for the nutrient requirement of enterocytes is not clear, but feed deprivation may depress cell regeneration and migration of enterocytes in the villi. Pigs fed a diet with added soybean oil or coconut oil alone had shorter and more slender villi in our study. The combination of soybean oil and coconut oil may have provided a more ideal fatty acid profile, which met the capacity for absorption of both saturated and unsaturated fatty acids by pigs. The reduction of villus height decreased total luminal villus absorptive area. This may have resulted in inadequate digestive enzyme development and (or) transport of nutrients at the villus surface. However, the way in which fat, particularly the combination of soybean oil and coconut oil, affects starter pig performance requires further work.

Digestibility data showed that the presence of fat in these diets tended ($P<.06$) to depress ileal DM digestibility. This may be one explanation for the slightly lower ADG of pigs fed supplemental fat during this period. A second hypothesis may be related to intestinal villus height, since jejunal villi were shorter, and absorptive area was reduced when a single fat was added.

Table 2. Effect of Fat Addition on Nutrient Apparent Digestibility[a]

Items	Control	Soybean oil	Coconut oil	Soybean oil + coconut oil	SE
Fecal digestibility, %					
DM	83.5	85.2	84.0	83.8	1.97
Crude fat[b]	40.8	80.1	88.0	85.6	5.33
CP	77.7	80.4	79.4	77.8	3.69
GE	85.3	87.3	86.8	85.3	1.98
Ileal digestibility, %					
Total fat[b]	78.0	85.5	86.1	87.5	6.07
DM[c]	85.2	78.3	80.3	79.7	6.06
Fatty acid:					
Short-chain[d]	95.5	39.0	89.5	95.8	56.9
Long-chain					
Saturated	70.8	60.6	66.1	71.9	19.8
Unsaturated[e]	86.9	83.7	62.7	78.2	7.8

[a]Each mean represents six observations; initial weight were 12.3 ± .5 lb, ending weight were 15.4 ± 1.0 lb.
[b]Fat sources vs control (P<.01).
[c]Fat sources vs control (P<.06).
[d]Soybean oil : coconut oil or coconut oil > soybean oil (P<.05).
[e]Control, soybean oil or soybean oil:coconut oil > coconut oil (P< .05); Soybean oil:coconut oil < soybean oil (P<.01).

The data from this study showed that fat digestibility is influenced by the chain length and degree of saturation of its fatty acids, with short and medium chain fatty acids being absorbed readily. Pigs fed diets with supplemental fat had higher (P<.02) N digestibility at d 11 postweaning, indicating that the pig's ability to use a supplemental energy source appears to improve N utilization.

The digestibility of medium chain fatty acids and long chain, saturated fatty acids tended to be greater during the early postweaning period, when the combination of soybean oil and coconut oil was supplemented. The higher villi also reflected the beneficial response to the fat combination addition.

In summary, pigs fed diets supplemented with a combination of soybean oil and coconut oil had slightly longer (P<.08) villi and higher (P<.12) apparent digestibility of medium chain fatty acids and N than pigs fed diets containing a single fat source.

Table 3. Effect of Fat Sources on Ileal Fatty Acid Digestibility[a]

Item	Control	Soybean oil	Coconut oil	Soybean oil + coconut oil	SE
C8:0	100.0	84.6	98.0	99.4	19.4
C10:0	98.8	86.6	95.8	98.2	17.0
C12:0[b]	87.6	95.9	90.4	96.6	5.5
C14:0[c]	93.7	54.6	86.3	94.3	38.5
C16:0[d]	-144.1	80.0	81.3	83.2	69.6
C16:1[e]	74.4	83.1	86.6	89.6	10.2
C18:0	52.0	59.9	68.4	70.0	21.9
C18:1	80.1	85.6	81.0	83.0	5.8
C18:2[f]	84.0	87.2	81.0	84.4	5.0
C18:3	64.0	85.4	58.0	79.9	24.5

[a]Each mean represents six observations.
[b]Soybean oil or soybean oil : coconut oil combination > control ($P < .02$), soybean oil : coconut oil > coconut oil ($P < .06$).
[c]Soybean oil : coconut oil combination> soybean oil ($P < .09$).
[d]Soybean oil, coconut oil or soybean oil : coconut oil combination > Control ($P < .01$).
[e]Coconut oil vs control ($P < .06$), soybean oil : coconut oil combination > control ($P < .02$).
[f]Soybean oil vs coconut oil ($P < .05$).

Table 4. Effect of Fat Sources on Villus Height and Crypt Depth[a] (μm)

Item	Control	Soybean oil	Coconut oil	Soybean oil + coconut oil	SE
Villus height[b]	201.3	185.7	186.3	213.3	53.0
Crypt depth[c]	179.6	235.0	225.1	208.8	43.5

[a]Each mean represents eight observations.
[b]Soybean oil or coconut oil vs soybean oil : coconut oil combination ($P < .08$).
[c]Control vs soybean oil, coconut oil or soybean oil: coconut oil combination ($P < .02$).